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Series Connected GaN Resonant Tunneling Diodes for Multiple-Valued Logic

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Abstract : III-Nitride resonant tunneling diode (RTD) is one of the most promising candidates for multiple-valued logic (MVL) elements. Here, we report a monolithic integration of GaN resonant tunneling diodes to realize multiple negative differential resistance (NDR) regions for MVL application. GaN RTDs, composed of a 2 nm quantum well embedded in two 1 nm quantum barriers, are grown by plasma-assisted molecular beam epitaxy on free-standing c-plane GaN substrates. Negative differential resistance characteristic with a peak current density of 178 kA/cm² in conjunction with a peak-to-valley current ratio (PVCR) of 2.07 is observed. Statistical properties exhibit high consistency showing a peak current density standard deviation of almost 1%, laying the foundation for the monolithic integration. After complete electrical isolation, two diodes of the designed same area are connected in series. By solving the Poisson equation and Schrodinger equation in one dimension, the energy band structure is calculated to explain the transport mechanism of the differential negative resistance phenomenon. Resonant tunneling events in a sequence of the series-connected RTD pair (SCRTD) form multiple NDR regions with nearly equal peak current, obtaining three stable operating states corresponding to ternary logic. A frequency multiplier circuit achieved using this integration is demonstrated, attesting to the robustness of this multiple peaks feature. This article presents a monolithic integration of SCRTD with multiple NDR regions driven by the resonant tunneling mechanism, which can be applied to a multiple-valued logic field, promising a fast operation speed and a great reduction of circuit complexity and demonstrating a new solution for nitride devices to break through the limitations of binary logic.

Keywords : GaN resonant tunneling diode, multiple-valued logic system, frequency multiplier, negative differential resistance, peak-to-valley current ratio
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